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A Solution in Search of a Problem[1]

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1. Satellite status report

The original title of my paper was much more prosaic—"Present and Future Meteorological Satellite Programs." It is appropriate, therefore, that I begin with a relatively brief status report on this program.

TIROS: As you well know, we have successfully placed into orbit six TIROS satellites (Fig. 1). Currently there are two satellites, TIROS V and VI, still providing useful data from space.[2] The present NASA program calls for five additional TIROS launches. In order to insure the availability of operational data until the next family of satellites—Nimbus—is able to provide observations on a regular basis, the Weather Bureau has scheduled two further additional launches in the TIROS series. These are referred to as the "operational" TIROS satellites.

TIROS SATELLITES

	LAUNCH DATE	USEFUL LIFE	INCLINATION
TIROS I	APRIL 1, 1960	2½ MO.	48 DEGREES
TIROS II	NOV. 23, 1960	10 MO.	48 DEGREES
TIROS III	JULY 12, 1961	4½ MO.	48 DEGREES
TIROS IV	FEB 8, 1962	4½ MO.	48 DEGREES
TIROS V	JUNE 19, 1962	STILL OPERATING	58 DEGREES
TIROS VI	SEP. 18, 1962	STILL OPERATING	58 DEGREES

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FIG. 1. The first six TIROS satellites.

In view of the continuing excellent performance of TIROS V and VI, our original launch date for

[1] Paper presented at the Third National Conference on the Peaceful Uses of Space, 3 May 1963, Chicago, Ill., as part of the Atmospheric Science Program of the University of Chicago Space Month Program.

[2] On 4 May 1963 after a record ten and one-half months of operation and more than 57,857 earth cloud cover pictures, TIROS V ceased its functioning, probably because of a shutter mechanism failure. Its place was taken by TIROS VII launched 19 June 1963.

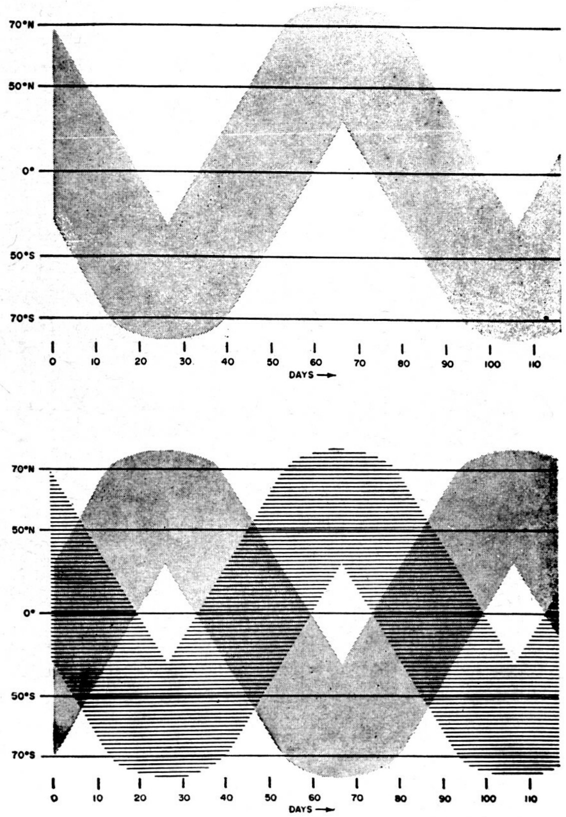

FIG. 2. Day to day latitudinal coverage of a single TIROS (above) and two TIROS in phase apposition (below).

the next TIROS has now been intentionally delayed twice. The new launch date will permit placing the next satellite into an optimum phase relationship with those currently aloft (Fig. 2). While TIROS V and VI are providing data in one part of the globe, the next satellite will provide data in another. This additional coverage will increase the frequency of observation during the hurricane season and thus assist in maintaining a continuous vigil over the area where these severe storms are born.

As was the case with all the previous R&D TIROS satellites, the planned additional five TIROS satellites will be able to provide data for operational use in current analysis and forecasting while at the same time executing their R&D missions. Some of these missions include: flying a 15-micron sensor, flight testing the Automatic Picture Transmission (APT) camera system, a TIROS polar launch, experimenting with a TIROS "cartwheel" configuration, and placing TIROS into a highly eccentric orbit.

Nimbus: The major objectives in developing the Nimbus satellite family have been to provide improvements in the following areas.

1) *Orientation:* Only during a very small portion of its orbit, does TIROS look straight down. The oblique angle of the majority of pictures causes difficulty in rectifying the pictures and in interpreting the cloud patterns. Nimbus will view the earth vertically during its entire lifetime.
2) *Coverage:* TIROS provides between 10–25 per cent of the global cloud cover per day. Meteorological requirements are for total global observations. Nimbus is to be launched in a near polar orbit and is to view every portion of the earth every day.
3) *Direct local readout:* The automatic picture transmission subsystem has been developed for Nimbus. Eventually, this system may represent one of the greatest contributions of the meteorological satellite program to local forecasting by providing pictures directly to the local meteorologist of his immediate area of interest.
4) *Lifetime:* An operational system should have a lifetime of at least six months and eventually one year or more. In addition to carefully engineered systems and reliable quality control in manufacturing, design redundancy plays a major role in achieving useful long life. Due to weight limitations imposed on it, the first Nimbus will be launched without this redundancy. However, the future developed operational spacecraft will include redundant systems.
5) *Growth potential:* Cloud pictures and the infrared radiation measurements satisfy the operational and research meteorological requirements only in part. The need exists for instrumentation to provide many more kinds of observations. Thus it is important that a meteorological satellite have the flexibility to accept without too much difficulty new instruments when developed. Nimbus is designed to do just that.

The Nimbus R&D program (Fig. 3) at present calls for four (4) launches over the period of the next few years. (These will be augmented by five launches funded by the Weather Bureau for providing "operational" data only). The first Nimbus is now well on its way toward completion.

The prototypes of the various subsystems have been tested successfully. It remains now to combine the developed Nimbus subsystems and to

METEOROLOGICAL SYSTEMS FLIGHT SCHEDULE

CALENDAR YEAR

	1962	1963	1964	1965	1966
TIROS R&D	3	3	2		
* TIROS OPERATIONAL		1	1		
NIMBUS R&D		1	1	1	1
* NIMBUS OPERATIONAL			2	2	3

■: APPROVED ▒: PLANNED
* U.S. WEATHER BUREAU FUNDED

FIG. 3. Meteorological Systems Flight Schedule.

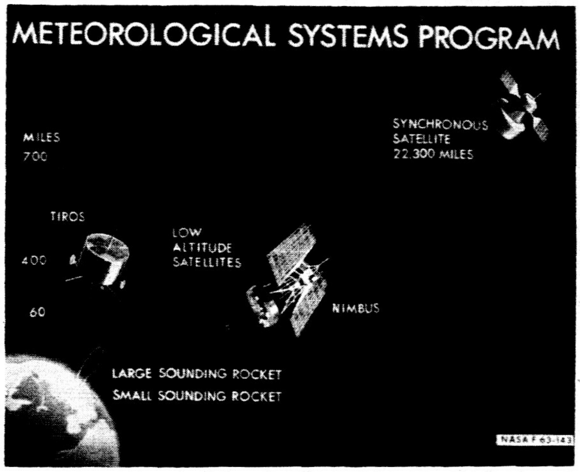

FIG. 4. Meteorological Systems Program.

check them out together as operating prototype and flight systems. When the spacecraft passes the testing procedures, we will be ready to launch Nimbus and we estimate this to be before the end of this year.

Synchronous Meteorological Satellite: (Fig. 4) This is our activity which relates to the development of a satellite having a synchronous or stationary orbit. Since it is not an officially approved flight program, we refer to it merely by means of this phrase "Synchronous Meteorological Satellite," rather than with a proper name. In this area we have concluded several study contracts which will assist us in assessing the problems involved in undertaking such a flight program. We are also considering alternative engineering systems that might satisfy the observational requirements.

In the future beyond this, we plan about one major R&D satellite launching per year in order to modify and improve developed systems or experiment with new ones.

This is a quick review of the present and future meteorological satellite programs—which, as I have said, was the original title of my talk.

2. Solution in search of a problem

And now I would like to discuss the new title and the reasons for the change. At a recent visit to the National Center for Atmospheric Research, I heard a senior research meteorologist refer to the Meteorological Satellite Program as "a solution in search of a problem."

Of course, he was not referring to the operational utilization of meteorological satellites. This has adequately been demonstrated many times over. Some specific applications are quantitatively shown in Fig. 5. In more general terms, meteorological satellite data have been used operationally in modifying surface frontal positions, in assisting the briefing of pilots, in locating and tracking tropical storms, in verifying and amplifying local analyses particularly in sparse data areas. The list continues and is long and impressive.

What, then, did he mean by "a solution in search of a problem"?

I believe he meant that from the research meteorologist's point of view, the data output from meteorological satellites was not immediately adaptable to the current stated problems being investigated by the research meteorologist. For example, the satellite data do not correspond exactly to the types of measurements being taken by the cloud physicist, nor do they contain the ver-

TIROS SATELLITES
OPERATIONAL SUPPORT ASPECTS

168,148	USABLE PICTURES
5,048	CLOUD COVER ANALYSES
712	SPECIAL STORM ADVISORIES
300	WEATHER ANALYSES IMPROVEMENTS
10	HURRICANES OBSERVED AND TRACKED
21	TYPHOONS OBSERVED AND TRACKED

ALL NUMBERS SHOWN ARE AS OF FEBRUARY 28,1963

FIG. 5. TIROS satellites—Operational support aspects.

tical distribution of quantitative measurements of atmospheric elements required by the numerical weather prediction study models of the atmosphere.

He thus meant that the data output—the solution—must be made to correspond more directly to the research meteorologist's requirements—the problem. And, in this I concur wholeheartedly.

This can be done in either of two ways:

1) The first is to have the researcher make the requirements more flexible, and use whatever data are available. The meteorologist can "try to learn the language of the satellite." He can study the data output for new information, new approaches, new concepts about the atmosphere and its behavior. As many observational scientists before him, who have been given a basically new observational tool, the research meteorologist must learn how to use his tool to observe, in order that he may synthesize and explain.

2) The other way is to control the nature of the data output. This is the way of the laboratory scientist who sets up experiments to study quantitatively a known, specific and limited problem. The kinds of measurements required are known, it is their magnitude and particularly their interrelationships that are being sought.

Let us consider each of these in turn. We shall see that each of these corresponds to different stages in the history of development of the meteorological satellite—which for the want of other terms, I shall call the Technological Development and Scientific Experimentation Periods respectively. We shall see that we have been in the Technological Development Period where participation by the research meteorologist was more or less limited to that of the observational scientist. We shall see that we are on the threshhold of the Scientific Experimentation Period where participation by the research meteorologist as an experimental scientist is possible and desirable.

3. The Technological Development Period

I think it is fair to say that the six successful launches of TIROS represent a source of pride for the United States space effort. TIROS has indeed been spectacular as a technological achievement. However, if we study the TIROS system carefully, we note readily that it is, in fact, an elementary flight system (Fig. 6). TIROS is a simple spin stabilized satellite. Its primary sensor is a TV camera to provide picture data. It also contains infrared radiation measurement experiments viewing selected portions of the visible and infrared radiation spectral range. The decision

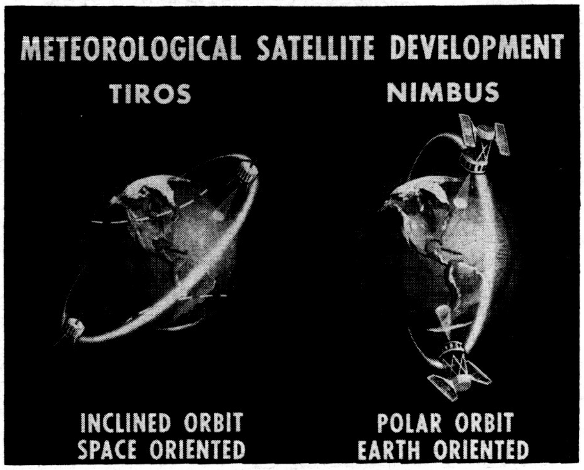

FIG. 6. Meteorological satellite development.

to include instrumentation for taking cloud pictures was undoubtedly a direct outgrowth of the experience over the past 15 years with instrumentated rocket nose cones. These contained recoverable film systems and indicated the feasibility of taking pictures from above. Also in the past there have been experiments and observations of heat budget measurements, and these too are repeated in the TIROS satellite. The measurement of radiation in specific spectral bands, however, was a relatively new experiment and points to the direction in which future experiments may well proceed. These measurements taken by the TIROS satellite in specific spectral bands are available for study and some experimenters have already begun to review and analyze these data.

From the point of view of a technological development and engineering accomplishment, the Nimbus program constitutes a dramatic and important step forward. As we have indicated, the Nimbus program is a major improvement over the TIROS program in each of the five following areas: orientation, coverage, direct local readout, lifetime and growth potential. In each of these, major breakthroughs were required. But it is important to remember that the basic meteorological sensors contemplated for Nimbus are essentially the same as those on board TIROS. Again there will be cloud cover pictures, although there will be more of them and they will be available more rapidly. Night-time cloud pictures may be possible using the 4-micron High Resolution Infrared Radiation detector (HRIR) measurements; when the Medium Resolution Infrared Radiometer is included it will provide measurements, in essentially the same spectral bands as TIROS.

The plans for future efforts indicate additional engineering developments. Developments are proceeding with an electrostatic tape camera to give still further improved cloud cover pictures; with non-destruct readout to permit additional contact with the satellite; with an image orthicon camera to permit nighttime TV; with nuclear power supplies to improve the power source; with improved control systems to provide orbit flexibility, etc.

During this period the data made available to the researcher by the meteorological satellite were limited by the technological potential of the satellite and by the limited experience with suitable satellite sensors. As we have already indicated, the picture data and the IR data from large portions of the globe comprised a source of new observations which had to be looked at, reviewed and studied for new information, new approaches and new concepts about the atmosphere and its behavior.

Both the Weather Bureau and NASA facilitated the acquisition of these data by the research meteorologist. In a great many instances copies of the data were given away for the asking. We conducted symposia in the rectification, analysis and interpretation of these data. Study efforts have been supported financially.

In general, the response of the researcher has been good. Many study efforts have been initiated in the universities and in private research institutions involving these data. The scientific literature contains an appreciable number of papers based on these efforts.

We hope that this aspect will become a permanent feature of the program, and the meteorologist will continue in his role as an observational scientist.

4. The Scientific Experimentation Program

We feel that with the successful flight of Nimbus, we shall have arrived at a major technological development milestone. Although, as I have indicated, technological development will continue, we shall be entering into the period where serious scientific experimentation is possible. We are entering into the period where the vitality and growth of the program will be determined largely by the participation and contribution of the scientific community. It is my hope that you will consider this matter seriously and determine for yourself the nature of this participation.

To stimulate this consideration on your part, I would like to suggest a few areas wherein, I believe, such participation and contribution may bear fruit.

1) *Participation within existing flight plans.* In connection with your own current research efforts, you may wish to ask for special satellite observations—either over particular areas or for particular times. We shall be happy to accommodate such requests whenever possible. Perhaps you can suggest modifications in our program which, while minor so far as implementation is concerned, will contribute significantly to your studies.

In this connection, I would like to become more specific. We are currently entering into the early planning phases for a future TIROS to be launched into an elliptical orbit. In about 1½ years from now, we hope to launch TIROS into a 300-mile perigee and 3,000-mile apogee orbit. This will be followed later by another TIROS whose apogee will range out to about 22,000 miles. Both of these experiments are to provide a view of the earth's atmosphere from various altitudes. We invite your thoughts with regard to the types of measurements and the types of experiments that best can be made from this type of a configuration. Are there special meteorological problems that can best be studied with this arrangement? Should supporting ground-based observations also be made? What kind, etc.?

2) *Participation in the planning of the Data Collection Satellite System.* We heard yesterday of the preliminary plans for this satellite that will interrogate automatic sensing and telemetering platforms and provide these data to a central collection station. Your help will be needed in the determination of what meteorological measurements to make, where to make them, and with what frequency. Also, the development of suitable sensing platforms must be undertaken.

3) The most exciting and undoubtedly the most difficult is the *participation in basic sensor development and experimentation.* As you well know, the satellite's information about the atmosphere and its properties is restricted to measurements of radiation in the electromagnetic spectrum. It is necessary to search this spectrum for significant bands or groups of bands that have a relationship—preferably a quantitative relationship—to some behavior or element of the atmosphere. Not only the visible and near infrared regions must be so studied but others such as the ultraviolet, the microwave region and sferics producing regions must so be reviewed. After the physical principles have been established, either theoretically or in the laboratory, actual satellite instrumentation can be considered. The development of a satellite spectrometer is proceeding in this direction. As you know, Kaplan suggested that measurements in the 15-micron region could yield a vertical dis-

tribution of temperature. Additional work in the Weather Bureau by Wark and Yamamoto limited this to three observations in the stratosphere. Based on this theoretical consideration, the Weather Bureau scientists have been experimenting with a laboratory spectrometer in this spectral region, and we feel that perhaps soon it shall be possible to proceed with a flight version for a satellite.

4) *Considering experiments to be performed in and on the earth's atmosphere* by means of satellites, as *preliminary to the investigation of atmospheres of other planets.* Successful experiments such as these will be indispensable in assisting in the interpretation of what we observe in and about the atmospheres of other planets.

More and more of this must be done, and we invite you individually and collectively to participate in this aspect of the program, to become experimenters and to suggest studies, in order to assist us to develop the meteorological satellite to its full potential. In this way, the data output—the solution—will better match the requirements—the problem—and there will no longer be a need for the kind of a search implied in the title of my paper.

I shall close with a word of caution. While we urge you to come forward with new ideas, we hope that you will first consider these ideas critically yourself. As serious scientists, I am sure you understand how important this is. I can mention the case of satellite radar as a good example of what I mean. The idea of having radar on board a satellite for measuring precipitation is most attractive. It was suggested several years ago and we have been talking about having it almost as long a time. Careful study has indicated, however, that serious problems exist in the basic technology involved. These limit severely the quantity of observations possible. A recent study concluded by Stanford Research Institute shows, moreover, that even if the technological difficulties could be overcome, the meteorological usefulness would be too limited to justify proceeding with such a development. We have put aside our flight experiment plans for a satellite radar consequently, until evidence can be presented to warrant a different course of action.

To sum up, the time is ripe now for you to consider becoming active and serious participants in this program—and, as such, we are anxious to hear from you and work with you.